# Valley-floor censuses of the Critically Endangered Yellow-crested Cockatoo *Cacatua sulphurea occidentalis* on Komodo Island, East Nusa Tenggara province, Indonesia, point to a steep population decline over a six-year period

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**The population of the Critically Endangered Yellow-crested Cockatoo *Cacatua sulphurea occidentalis* in Komodo National Park, Komodo Island, East Nusa Tenggara province, Indonesia, is thought to be second largest, but has been little studied. In September–October 2005, we surveyed cockatoos from vantage points overlooking five coastal valleys, each one on three consecutive days, and in September 2006 counted cockatoos in Loh Sebita valley on five consecutive days. Our method reduced the possibility of double-counting birds because on each day only the single largest count of cockatoos was used. We compared our 2005 and 2006 data with population census counts from the same valleys using the same method in September–October 2000. We also collated opportunistic counts of the species on Komodo made between 1996 and 2015 and checked whether temporal trends were apparent between two 10-year periods. Nest and breeding data were also collected. A total of 137 cockatoos was recorded in 2005 compared with 340 in 2000, with census counts declining by an average of 60%. In Loh Sebita valley the population declined by 41% between 2000 and 2006. A total of 19 active nests was located, with 25 nestlings/juveniles recorded, mostly in tall and smooth-trunked *Sterculia foetida*, *S. oblongata* and *Corypha utan* trees, which are apparently selected to reduce nest predation. Vantage point census counts are a suitable method on Komodo because inland topography renders cockatoo flocks easily detectable from ridges, although greater survey effort is needed to reduce margins of error. The cause(s) of the sharp population decline remain unclear but trade is the most likely driver, with other factors such as breeding failure possibly involved. Annual population and habitat monitoring is needed on Komodo to confirm the causes of decline and specific patrolling is needed to monitor nests.**

## INTRODUCTION

The Critically Endangered Yellow-crested Cockatoo *Cacatua sulphurea* is one of the world's rarest parrots with a global population estimated to be between 1,500–7,000 individuals. The main threats are ongoing capture for trade, loss of tropical forest habitat to selective logging and swidden agriculture, and killing of birds as agricultural pests (BirdLife International 2016). A major population crash occurred in the 1970s, when it was trapped in very large numbers (BirdLife International 2001). Records held by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) show that at least 96,785 birds were exported from Indonesia between 1981 and 1992 (BirdLife International 2001). Harris *et al.* (2015) examined patterns of international trade in Yellow-crested Cockatoo and found that market volumes and prices of birds increased rapidly from 1980 to 1992 as the wild population was decimated.

According to Collar & Marsden (2014), Yellow-crested Cockatoo populations on Nusa Penida and Lombok and east to Alor, including Komodo, are the subspecies *occidentalis*, with *parvula* restricted to Timor. Although *occidentalis* historically occurred widely in Nusa Tenggara, its populations on Lombok, Sumbawa, Flores and Alor have been decimated by captures for trade (BirdLife International 2001). The single largest population is believed to persist on Komodo where, during a 17-day survey between 3 September and 1 October 2000, a total of 366 Yellow-crested Cockatoos were counted in eight valleys (each surveyed for 2–3 days), and it was estimated that a further 160 were present at unsurveyed sites, hence a total figure for Komodo of 500 birds; the highest individual count was 190 in Loh Liang, the largest valley surveyed (Agista & Rubyanto 2001).

Our study in 2005 focused on the five valleys, Loh Sebita, Loh Liang, Loh Pinda (named Loh Lawi in Agista & Rubyanto 2001), Loh Wau and Loh Wenci (Figure 1), where Agista & Rubyanto (2001) recorded 340 cockatoos—93% of their total count. We exclude data from one site (Loh Gebah with 36 birds) included in population estimates by Agista and Rubyanto (2001) because these data were collected by Komodo National Park staff in 1995 or before. The Loh Gebah count data were also mentioned by BirdLife International (2001) under the incorrect assumption that they were also collected in late 2000. We here consider Loh Liang as a single valley site and pool data of Agista & Rubyanto (2001) for the two sites 'Poreng' and 'Banu Nggulang' listed for this valley (BirdLife International 2001). The main objective was to census cockatoos in valley-floor samples and compare our results with the 2000 baseline. These results were included in a project report cited by BirdLife International (2016), but here we provide more detail. Since our observations, there has been one further brief survey of cockatoos on Komodo which was restricted to Loh Liang, the largest valley (Nandika *et al.* 2012).

We also noted aspects of nest biology, which may be a key factor limiting population size (Walker *et al.* 2005), and describe habitat composition and extent. These studies are vital to assist the Komodo National Park management to develop conservation strategies, identify work priorities and implement site management (Pet & Subijanto 2001). Because Komodo has been one of the most regularly visited sites in the Lesser Sundas since the 1980s, we reviewed opportunistic counts of Yellow-crested Cockatoos by visiting ornithologists and birdwatchers to determine if temporal trends were apparent.

## STUDY AREAS AND METHODS

Komodo Island (8.594°S 119.431°E) is the largest (311 km$^2$) of the islands making up Komodo National Park, which is dedicated primarily to the preservation of intact savannah landscapes, the iconic Komodo Dragon *Varanus komodoensis*, and a rich and diverse marine fauna (PHKA 2000). The island has a rugged topography with small (0.42–6.24 km$^2$), narrow (<4 km wide), lowland (below 150 m) coastal valleys, bordered by ancient steep volcanic hills and ridgelines which rise 200–600 m above the valley floors. The valleys are generally linear features which run inland more or less at right angles to the coastline and are bounded by moderately

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**Plate 1.** View over the Loh Liang valley showing closed deciduous forest in the valley through to grassy and palm-dominated savannah on ridges, March 2006.

steep to steep slopes and ridges. Komodo Island has a tropical dry climate dominated by the westerly monsoons, with the monsoon season (December–March) bringing most of the rainfall and the south-east trade winds bringing mainly dry weather during the intervening eight months. Annual rainfall (about 800 mm) is lower than neighbouring Flores (Labuanbajo, 948 mm), Sumbawa or Sumba (RePPProT 1989). Droughts and occasional flooding occur.

**Figure 1.** Survey sites (hatched areas) and Yellow-crested Cockatoo nest sites (black dots) on Komodo Island. 1 Loh Sebita, 2 Loh Liang, 3 Loh Pinda, 4 Loh Wau and 5 Loh Wenci.

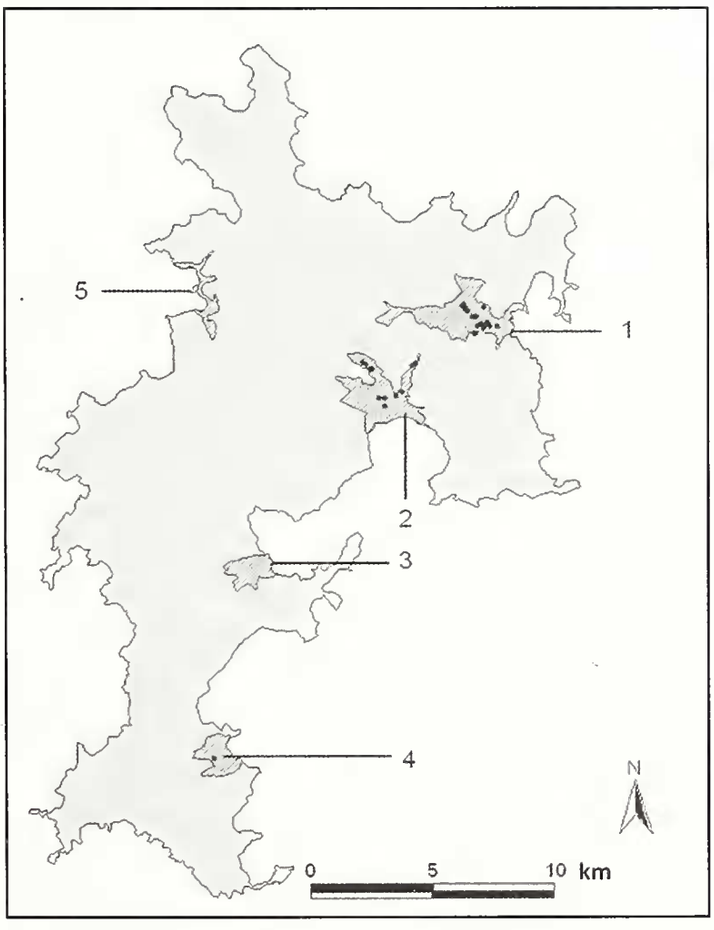


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**Plate 2.** Pair of Yellow-crested Cockatoos *Cacatua sulphurea occidentalis* at nest-hole in *Sterculia foetida* tree, March 2006.

During the dry season, May–November, there is very little rainfall, increasing the risk of droughts which usually occur between July and October, the driest part of the year. They also bring the risk of wildfires, which have been known to cause damage in the past.

Our 2005 study took place in the five valleys where Agista & Rubyanto (2001) recorded most cockatoos: Loh Sebita, Loh Liang, Loh Pinda, Loh Wau and Loh Wenci (Figure 1). Loh Liang, the largest valley, is a centre of tourism and other human activity, because it is near Komodo village, the largest settlement in the park; the park headquarters are located there.

## Habitat types and extent

Valley-floor area (below 50 m altitude) and the habitat composition in each of the five valleys were analysed using LandsatTM images (1999) by creating polygons in ArcView 3.2 (ESRI). We classified terrestrial habitats (excluding mangrove which covers only about 100 ha on Komodo) into one of four habitat types, following Monk *et al.* (1997). During an earlier study of the Komodo Dragon, habitat was ground-truthed by categorised types including dominant tree species and canopy cover at a series of GPS points. These points were then used as references for satellite image analysis as part of a supervised classification. A map was made in Arcview including

sample points of each habitat type. A 1999 Landsat image was processed using Erdas Imagine to obtain a map with four habitat types based on ground-truthed reference points. Using Arcview we analysed the extent ($km^2$) of each habitat type and calculated the proportion of each habitat type island-wide and in our valley-floor study areas (Figure 1).

Natural habitat types on Komodo are: (a) savannah—an open habitat, with less than 15% canopy cover, up to 10 m tall (Monk *et al.* 1997), dominated by the palm *Borassus flabellifer* and *Ziziphus* sp. with a grassy understorey on hillsides; (b) open deciduous monsoon forest—a coastal valley community dominated by tropical dry forest trees such as *Tamarindus indica* and *Sterculia oblongata* growing to 20 m tall with 50–70% canopy closure (Monk *et al.* 1997); (c) closed deciduous monsoon forest—a denser monsoon forest that exists in coastal valleys, characterised by *Tamarindus indica* and *Ficus* sp. trees; and (d) closed evergreen forest—a tall dense tropical forest, very limited at lower altitudes, found mainly above 500 m and characterised mostly by bamboo, rattan, *Podocarpus neriifolia* and *Calophyllum spectabile* (Auffenberg 1981).

### Population censuses

In the 2000 census Agista & Rubyanto (2001) counted cockatoo populations in the morning and afternoon on two consecutive days (four counts) directly from lookout points about 10 m above canopy height on ridges overlooking each of the valleys. The hilly topography of Komodo Island allows excellent vantage points above monsoon forest in valleys to count cockatoos, and the birds' behaviour of flying between roosting and feeding sites in the forest means that a high proportion of birds are likely to be detected in each valley (Agista & Rubyanto 2001). Although it is very likely that birds move widely between valleys in larger time-frames, the reasonable assumption behind this survey technique is that numbers of birds present in valleys over a period of a few weeks are probably fairly constant and reflect a degree of temporary site-fidelity. We therefore sought to replicate this technique in our own census five years later.

The number of Yellow-crested Cockatoo in the valley floors was estimated using direct censuses (Bibby *et al.* 2000) from vantage points, about 50 m above sea level, on ridges overlooking each valley (Plate 1). The census was carried out between 13 September and 15 October 2005 prior to the main breeding season, and at the same time of year and using the same protocols as Agista & Rubyanto (2001). Cockatoos were counted each morning (06h00–08h00) for three consecutive days (three counts), as they flew from roosting sites to presumed feeding areas elsewhere in the valleys. From 15 to 19 August 2006, Loh Sebita valley was re-surveyed for five consecutive mornings (06h00–08h00) and afternoons (16h00–18h00)—ten surveys in all.

We avoided double-counting by only accepting the size of the single largest flock seen during the count period or the sum of several flocks seen very close in time but geographically separated from each other (about 100–400 m apart). The results therefore represent a conservative count, with some birds not detected by the survey team because they either broke into smaller groups or were foraging in the canopy or were otherwise obscured. To assess the density of cockatoos in each valley we divided the highest single-day count in a valley by its area (derived as described above).

### Nesting ecology

During March and April 2005, when nestlings were about to fledge and were more conspicuous in nest holes (Agista & Rubyanto 2001), we made systematic searches in each valley to locate nest trees. Several observers (3–6 people) walked consecutive parallel transects approximately 25 m apart to find potential nest trees. The length and number of transects in each valley were determined by valley area and topography. We only surveyed valley floors to an altitude of 60 m because expert local knowledge indicated that nesting was confined to lowland valleys. Each valley was searched for between 3–6 days, a total of about 21 days of effective survey (excluding travel to and from sites). Nests were deemed to be active if there were young directly observed at the edge of tree-holes, immature birds on branches in the nest tree, or adults guarding the nesting location (Plate 2). A total of 28 trees with 37 potentially active nest-holes were found with each tree having 1–3 holes suitable for cockatoos. Most were found on the first day, then on the following days observations were made to confirm whether they were active and how many young birds were present. To confirm whether potential nest trees were in active use, repeated observations 15–30 minutes in length were made at all active nests in a single valley surveyed in a single day. Follow-up visits to each active nest were repeated over the following 3–5 day periods in the three valleys where active nests were found. Effort to document nest activity and the number of young cockatoos at each active nest tree therefore varied from a minimum of 45 minutes to a maximum of approximately 2.5 hours. Of the 37 holes found, 19 were active, each one in a different tree. To minimise disturbance, trees were not climbed to inspect nests, with observations being made using binoculars from a distance about 30 m.

We recorded a suite of geographic and environmental information for each nest including coordinates using a Garmin Etrex Vista GPS, altitude (m), broad vegetation type (savannah, open deciduous monsoon forest, closed deciduous monsoon forest) and nest tree species. Structural characters of each nest tree were also recorded: diameter at breast height (dbh), tree height (m), and nest height (m above ground). Tree and nest height were measured with a Suunto Clinometer.

### Opportunistic cockatoo counts by visitors

We reviewed Yellow-crested Cockatoo counts from ornithological trip reports, birdwatching tour reports and eBird (eBird 2015) for the period 1996–2015, with the objective of checking whether temporal trends were apparent. We took this action because we believed these secondary data were independent and unbiased. However, the data were subject to many limitations: the number of visits has increased since 2005, with possibly three times as many visits between 2006–2015 as during 1996–2005; the data were probably mostly obtained from a geographically small part of the Loh Liang valley/main tourist area, because most tour groups land there and pick up the necessary guide to accompany them as they look for Komodo Dragons—the main focus of almost all visits together with the opportunity to see Yellow-crested Cockatoos. The duration of many visits was a half-day or less and the habitats visited as well as the distance inland ventured by the groups was to some extent determined by how soon the two primary objectives were found, seen and photographed to the satisfaction of the participants (B. R. Sykes *in litt.* 2016). Written observations in several accounts included statements such as 'several birds' and 'several pairs' and thus were evidently subject to interpretation; likewise, one record of 'as many as 100 birds' (BirdLife International 2001) was considered to be an outlier which would tend to skew any trend.

### Statistical analysis

A Wilcoxon rank-sum test was used to examine whether there were any differences between the median rank of Yellow-crested Cockatoo census count data from the five valleys in 2005 compared to the 2000 data. We tested whether there were differences in Yellow-crested Cockatoo census counts done in the morning compared to the afternoon at Loh Sebita in 2006 using a Wilcoxon rank-sum test. For the 2006 data, we graphed the 95% confidence intervals of each consecutive census count, and also estimated the number of census counts that would be needed to achieve a low margin of error (0.5), with 95% confidence using the calculation

**Table 1.** Coverage (km²) and % (in brackets) of the main vegetation types of the five valleys most used by Yellow-crested Cockatoo on Komodo Island.

| Name of valley | Loh Sebita | Loh Liang | Loh Pinda | Loh Wau | Loh Wenci | Total for the 5 valleys | All Komodo valleys | Komodo Island |
|---|---|---|---|---|---|---|---|---|
| **Area** | **4.27 km²** | **6.24 km²** | **1.80 km²** | **0.86 km²** | **0.42 km²** | **13.59 km²** | **35.71 km²** | **311.66 km²** |
| Vegetation type: | | | | | | | | |
| Savannah | 1.94 (45.4) | 2.32 (37.2) | 1.43 (79.4) | 0.31 (36.1) | 0.17 (40.5) | 6.17 (45.4) | 23.14 (64.8) | 185.02 (59.3) |
| Open deciduous monsoon forest | 2.23 (52.2) | 3.64 (58.3) | 0.37 (20.6) | 0.27 (31.4) | 0.10 (23.8) | 6.61 (48.6) | 11.96 (33.5) | 79.33 (25.4) |
| Closed deciduous monsoon forest | 0.10 (2.3) | 0.27 (4.3) | 0 | 0.28 (32.6) | 0.15 (35.7) | 0.80 (5.9) | 1.05 (2.9) | 38.63 (12.4) |
| Closed evergreen forest | 0 | 0 | 0 | 0 | 0 | 0 | 0 (0) | 8.65 (2.8) |

n = (1.96 [confidence limit for standard normal distribution] × standard deviation of counts/0.5)².

## RESULTS

### Characterisation of habitats on Komodo Island

Based on the 1999 LandsatTM image, the overall vegetation cover on Komodo comprised savannah (59.3%), open deciduous monsoon forest (25.4%), closed deciduous monsoon forest (12.4%), and closed evergreen forest (2.8%) (Table 1). The satellite imagery showed that open deciduous monsoon forest and tropical deciduous monsoon forest typically occur at lower altitudes (below about 50 m) in coastal valleys. The five valleys selected for survey in 2005 on the basis they were the locations most used by Yellow-crested Cockatoo in 2000, were dominated by open deciduous monsoon forest (48.6%) characterised by *Tamarindus indica*, *Sterculia foetida*, *Corypha utan* and *Schleichera oleosa*, and savannah (45.4%) characterised by *Borassus flabellifer*.

### Comparison of population counts

During the 2005 study, a total of 137 Yellow-crested Cockatoos was recorded from the five valleys, an overall decline of about 60% since 2000 (Table 2). The largest census count was 62 birds in Loh Liang whilst the lowest was three birds at Loh Pinda (Table 2). The overall density of Yellow-crested Cockatoo in 2005 was 10.1 per km² (Table 2) with the highest at Loh Wau (18.6 per km²) and lowest at Loh Pinda (1.7 per km²). There was a statistically significant difference in the mean ranks of cockatoos counted in valleys during the two study periods (Wilcoxon rank-sum test W= 32.5, p <0.05).

In 2006 at Loh Sebita a maximum of 48 cockatoos (mean/min: 31.7/13; 95% confidence interval: 37.3–54.7) were counted in 10 censuses. The mean number of birds counted in the afternoon was less than morning census counts (26.6 vs. 36.6; Wilcoxon rank-sum test R= 33, p <0.05). Afternoon census counts were also more variable than morning counts (SD = 17.1 vs. 10.9). To achieve an acceptably low margin of error at Loh Sebita (0.5 or 5%), with 95% confidence, i.e. n = (1.96 × 8.8/0.5)², a total of 74 cockatoo census counts would be needed.

**Table 2.** Current and Agista & Rubyanto (2001) census counts (highest counts, mean and range for 2005 data) of the Yellow-crested Cockatoo in five valleys on Komodo. Density is largest census count for a valley, divided by its land area.

| Site (survey date) | Max. count 2000 (n=4) | Counts 2005 (n=3) | Density/km² (2000) | Density/km² (2005) | Change (%) |
|---|---|---|---|---|---|
| Loh Sebita (13–15 Sep) | 82 | 50,46,41 | 19.20 | 11.71 | –39 |
| Loh Liang (29 Sep–1 Oct) | 190 | 53,46,62 | 30.45 | 9.94 | –67 |
| Loh Pinda (2–4 Oct) | 18 | 3,3,3 | 10.00 | 1.67 | –83 |
| Loh Wau (25–27 Sep) | 44 | 16,9,15 | 51.16 | 18.60 | –64 |
| Loh Wenci (13–15 Oct) | 6 | 6,6,6 | 14.29 | 14.29 | 0 |
| Total/mean density | 340 | 137 | 25.02 | 10.08 | –60 |

**Table 3.** Mean characteristics of Yellow-crested Cockatoo nest trees found on Komodo in 2005. dbh = diameter at breast height.

| Species | No. nests | dbh (cm) | Tree height (m) | Nest height (m) |
|---|---|---|---|---|
| *Sterculia faetida* | 7 | 67 (51–80) | 16.7 (9.6–23.0) | 11.4 (8.9–16.3) |
| *Sterculia ablangata* | 7 | 54 (48–66) | 18.7 (15.2–29.1) | 12.5 (7.2–21.3) |
| *Corypha utan* | 3 | 63 (57–72) | 13.9 (12.5–13.7) | 13.1 (12.5–13.6) |
| *Ficus* sp. | 1 | 172 | 17.3 | 15.6 |
| *Barassus flabellifer* | 1 | 38 | 18.0 | 16.0 |
| Overall | 19 | 79 (38–172) | 16.9 (9.6–29.1) | 13.7 (7.2–21.3) |

### Opportunistic observations

It was difficult to draw firm conclusions from the analysis of visitor reports from published and unpublished sources. There were very large variations in the numbers of cockatoos reported throughout the period. However, there was a significant increase in the number of sources reporting low counts of only 4–6 birds per visit from three visits out of seven between 1996–2005 to 15 out of 24 visits between 2006–2015, although in contrast a typical morning visit in June 2015 reported 40+ birds, probably the highest opportunistic total on record during this period (Birdtour Asia 2015). The second highest count was more than 30 birds in August 2008 and at least 20 birds were seen during eight visits—three in the first decade and five in the second decade.

As summarised in the methods section, methodology, skill and objectives of visitors were unknown and uncontrollable variables; nevertheless there was undoubtedly a decline in the median number of cockatoos recorded per visit in the period between 2006–2015 compared with 1996–2005.

### Nest ecology

In 2005, a minimum of 25 nestlings or recent fledged birds were observed in the following locations: in Loh Sebita, of seven nests three held one young, four contained two; in Loh Liang, of 11 nests nine held one young, two contained two; and in Loh Wau, one nest had one young (Table 3, Figure 1). Nests were more frequently located in open deciduous monsoon forest (68%) than savannah (36%) or closed deciduous monsoon forest (5%). Yellow-crested Cockatoos mainly nested in *Sterculia foetida* or *S. oblongata* trees in Loh Liang valley and *Corypha utan* in Loh Sebita; they selected tall trees and nested high in them (Table 3).

## DISCUSSION

Our census counts did not record all Yellow-crested Cockatoos in the five valley floors surveyed on Komodo, but probably represent a high proportion of the birds using this habitat. These counts declined by an average of 60%, from a census count of 340 individuals in 2000 to 137 in 2005. At Loh Sebita counts declined from 82 birds in 2000 to 50 in 2005 and 48 birds in our 2006 survey, a 41% decline. Despite statistical considerations, and the potential for birds to move between valleys within and between survey periods, we are confident that the steep decline is real for the following reasons: (1) the linear valley-floor topography from coast to inland is well suited to vantage-point surveys, and the small size of valleys and high detectability of white cockatoos mean that census counts of a high proportion of birds present in the valley floors

are relatively straightforward; (2) census counts in the four largest valleys all showed the same negative trend; (3) we recorded the same number of cockatoos in Loh Wenci, the smallest valley, as Agista & Rubyanto (2001), which we interpret as a complete or near-complete census, although they may not have been the same individual birds; (4) Nandika *et al.* (2012) used transect methodology in May 2012 and walked three different transects over three consecutive days in Loh Liang valley, during which they counted a total of 73–86 birds, a decline around 60% since 2000. Agista & Rubyanto (2001) estimated that the Yellow-crested Cockatoo population on Komodo in 2000 was 500 birds. A similar extrapolation of our data, including unsurveyed habitat, yields a total of approximately 181 individual birds (137 birds plus approximately 44 birds [32%] from unsurveyed areas in 2005).

All populations of Yellow-crested Cockatoo have been devastated by captures and trade over the last 40–50 years (BirdLife International 2016). There is much uncertainty about estimates of population sizes on most islands (Collar & Marsden 2014) because of lack of specific surveys and reliance on approximate data. On many islands within the original range of the Yellow-crested Cockatoo it would no longer be possible to make systematic surveys because birds occupy only a small percentage of their former habitat, and it seems that only on Sumba, Timor-Leste and perhaps Komodo do populations of more than about 200 birds remain (BirdLife International 2001, 2016, Collar & Marsden 2014). We acknowledge that the few cockatoo surveys on Komodo have had methodological limitations, with the 2000 survey based on four counts and ours on three (and 10) counts, while Nandika *et al.* (2012) surveyed birds along single line transects on three consecutive mornings in Loh Liang, the largest valley. However, surveying by different observers is unlikely to be a major source of data variability for such a conspicuous species, and we are confident that our methods in the five valleys were similar to those of Agista & Rubyanto (2001).

A number of factors such as nest failure, high rates of predation, and loss of tree holes might be involved in the rapid population decline of cockatoos, but the major driver is likely to be ongoing clandestine capture for trade (see, e.g., Eaton *et al.* 2015). The main motivation for this is described by Harris *et al.* (2015): as the wild population declines the price increases, which maintains or increases levels of illegal poaching.

There is very little specific information on cockatoo poaching on Komodo. As stated by BirdLife International (2001): '*parvula* [*occidentalis*] survives best on Komodo owing to the protection afforded by Komodo National Park'. As early as 1993 park guards reported to Butchart *et al.* (1996) that cockatoo trapping did occur, but 'in remote parts of the national park away from the well-guarded park headquarters'. Indeed a high proportion of cockatoos have been recorded in Loh Liang valley near park headquarters: 190 birds (56%) of all cockatoos recorded in 2000 (Agista & Rubyanto 2001) and 62 birds (45%) in this study. Agista & Rubyanto (2001) noted that the presence of poachers who illegally hunted Javan Rusa Deer *Rusa timorensis* might lead to opportunistic shooting or trapping of cockatoos. They, like ourselves, had no direct observations of cockatoo poaching, but were informed that cockatoos sold in December 1999 at Sindu market, Mataram, Lombok, were sourced from Nusa Tenggara including Komodo Island. Although rangers do undertake regular patrols on Komodo and Rinca primarily for habitat security (Purwandana *et al.* 2014), specific patrols may be necessary for cockatoos, particularly around nest sites during the breeding season.

Our observations of 19 active nests are not substantial enough to infer whether poor breeding output might be a factor associated with the decline of cockatoos on Komodo. There are also no empirical data available on tree-hole availability. Lowland valleys offer strikingly different habitat compared with savannah vegetation on ridges and slopes, with the largest trees with greatest girths present in lowland valleys. Expert opinion indicates that cockatoos only breed in lowland valleys on Komodo. Tree-holes develop in old trees, with some estimates in Australian *Eucalyptus* that hollow formation begins after trees reach about 100 years old (Wormington & Lamb 1999). There is no regional information on the rate at which trees develop hollows, but palms like *Borassus flabellifer* probably develop holes much more quickly than tropical forest trees. Lowland valleys cover just 11.5% of the island (Table 1), which suggests that large and tall trees with suitable tree-holes could be very limited on the island.

The rapid decline we describe seems unlikely to be caused primarily by changes in breeding success, particularly in such a long-lived bird. Recent workers have speculated on the impact of arboreal juvenile Komodo Dragons, which are known to be a predator of cockatoos at nest-holes (D. Agista *in litt.* 2000). Predation by Komodo Dragons on cockatoos has undoubtedly occurred for many tens of thousands of years, but conceivably its impact is now proportionately greater as cockatoo populations have declined while Komodo Dragon numbers have remained stable (Purwandana *et al.* 2014). We found that cockatoos select tall trees with smooth bark for nesting, thereby presumably reducing access by arboreal predators such as juvenile Komodo Dragon and Common Palm Civet *Paradoxurus hermaphrodites*. In 2000, cockatoos were found to be nesting in nine dead *Borassus flabellifer* palms, using the hole at the top of the tree, and also a Mangrove Apple *Sonneratia alba* (Agista & Rubyanto 2001). Straight bark-free palms may also reduce predation, while mangrove habitat is little used by Komodo Dragons (Purwandana *et al.* 2014). Other factors, such as exceptionally high rainfall during the breeding season, have been shown to affect breeding success in Yellow-crested Cockatoos on Sumba (Walker *et al.* 2005). Use by cockatoos of dead palms with hollows exposed to rain, direct sun and heat would also tend to reduce breeding success.

Collar & Marsden (2014) provided a brief update on population sizes of the various subspecies. Apart from the tiny *abbotti* population—18 birds in 2013 (Nandika *et al.* 2013)—all populations appear to be in decline with more than 50–70% of the remaining population of subspecies *occidentalis* present on Komodo. However, the situation on the island of Rinca (which forms part of the Komodo National Park) is worth noting. In October 2000, Agista & Rubyanto (2001) counted 22 (Kampung Rinca site: 19–20 October 2000) and 32 cockatoos (Kampung Kerora site: 17–18 October 2000) during censuses on Rinca, and estimated that approximately 100 birds might be present. In July 2014 during a university undergraduate study in Mbeliling, western Flores, flocks of 69 and 15 birds were observed, and images of a flock of 40 birds were obtained; the observations were made only a few km from Rinca Island, and Aziz (2014) considered that the cockatoos had originated from Rinca and were using nearby Flores for feeding. This evidence is too anecdotal to interpret, but it engenders a degree of optimism and suggests that the situation on Rinca merits further study.

## CONCLUSIONS AND RECOMMENDATIONS

We are confident that the Yellow-crested Cockatoo population on Komodo suffered a steep decline between 2000 and 2005. Ongoing population monitoring is needed; we are aware that Komodo National Park staff have done such monitoring but we were unable to access these data and monitoring apparently stopped in mid-2014 for lack of funding (Muthiah 2015). The vantage-point counts used here are a suitable survey method, but sample sizes need to be increased by surveying both morning and afternoon for 3–5 days in each valley location and, where possible, having two independent simultaneous counters positioned on ridges/hillsides at least

400 m apart. This would increase the number of cockatoo counts to a minimum of 12 (3 days) or up to 20 (5 days), which would tend to reduce error in count estimates.

Understanding trends in the cockatoo population should be the highest priority but, if adequate resources were available, more detailed work to understand factors limiting populations would also be valuable, including identifying food tree species and their annual productivity of fruit, seeds, nuts and flowers, as this might influence cockatoo survival and reproduction. Assessments of tree-hole availability, mapping and monitoring of active nest sites, as well as specific ranger patrols near the main nest sites, would be helpful. Gathering information on cockatoo poaching has been difficult, but interviews with park rangers and with traders in regional markets (e.g. Lombok) may be useful. Komodo is accessible and offers excellent opportunities for further study of the cockatoo, and could be made a high priority for research by national university students and park rangers.

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